ELECTRICAL BLASTING AT MIAMI COPPER CO. MIAMI, ARIZ.

BY ALLEN D. LOOK AND ERNEST R. RODRIGUEZ

* * * * * * * * * * Information Circular 7567

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by

Allen D. Look[1/] and Ernest R. Rodriguez[1/]

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INTRODUCTION

The underground mine of the Miami Copper Co. has operated since 1927 without a fatality from blasting or the handling of explosives. To improve safety and efficiency, electrical blasting has been used exclusively since 1934. During the period January 1, 1934, to December 31, 1948, inclusive, over 4,000 tons of explosives were used to produce 60,925,071 tons of ore with 896,760 feet of development footage and 2,591,788 square feet of undercut area.

The purpose of this paper is to recount the company's precautions to insure safe handling of explosives at this operation, where safety involves careful planning rather than "trial and error."

GENERAL INFORMATION

The Miami Copper Co. operates an underground mine in a large, low-grade, porphyry copper deposit near Miami, Ariz. The deposit contains numerous fractures and planes of weakness, which contribute to ease of working the ore bodies by the block-caving method of mining.

An individual stope-caving method is used with stopes 150 feet by 200 to 300 feet and 30- to 50-foot pillars between stopes. After the stope is undercut, the ore is drawn through the draw raises on the grizzly level, and thence through the transfer raises to the ore chutes on the haulage level.

Access to the mine is by four active shafts, three of which are primarily for ventilation. No. 5 shaft is used for both hoisting and service. There are four operating levels in the mine. The elevations of the grizzly levels are governed by the contour of the bottom of the ore body and therefore vary in different locations in the mine.

Grizzly levels are on the 850, 900, and 975 levels. The 1,000 level is the haulage level.

This mine operates in very low-grade ore and requires economical handling of large tonnages safely and efficiently.

ACKNOWLEDGMENTS

The authors express their appreciation for the courtesies shown them by the mine officials and employees of the Miami Copper Co. and for their assistance in enabling preparation of this circular. Special acknowledgment is made of the helpful suggestions given by J. W. Still, mine superintendent.

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EXPLOSIVES AND DETONATORS

Only two types of explosives are used in the mine. To blast drilled rounds, the holes are loaded with 1-1/8- by 8-inch cartridges of 45-percent strength semi-gelatin dynamite. To blast raises and chutes that are "hung," and for "bulldozing" of boulders, 3- by 4 1/2-inch cartridges of 40-percent strength semigelatin dynamite are used. The latter are called "cone bombs" locally because of the cone-shaped depression on one end that directs the explosive force. The advantage of the cone-shaped charge is that, where it can be placed properly, the force is directed where it will do the most good, and therefore timber in raises is protected from excessive shock. The 1-1/8- by 8-inch cartridges also are used to blast raises and hung chutes.

The properties of the explosives are given by the manufacturer, as follows:

Strength, percent	Velocity, ft./sec.	Density Ctgs. - 1 1/8" x 8" per 50 lb./case
45	12,800	147
40	11,500	160

The explosive also is described by the manufacturer as having enough cohesiveness to load well in "uppers," satisfactory fume characteristics for underground use, and a high velocity even when detonated without confinement.

Electric detonators (No. 6 strength) are used in primer cartridges, "zero-delay" electric detonators with 3-foot leg wires are used in chute and raise blasting, whereas 0 through No. 7 delay caps with 8-foot leg wires are used with all primary blasting. The leg wires are shunted by the manufacturer to prevent premature firing from accidental contact.

STORAGE

Surface Magazines

Four permanent, building-type, surface-storage magazines are situated in an isolated area. They are partly barricaded because of construction in hillside excavations; access to them is by a private road, which is kept in good condition.

Two of the magazines, identical in size and construction, were completed recently (fig. 1). They were constructed according to Bureau of Mines recommended standards.2/ The walls, 11 inches thick, are built on a concrete foundation that comes to the floor level. They are made of a weak mixture of sand and cement and are lined on the inside with tongue-and-groove flooring

2/ Harrington, D., and East, J. H., Jr., Safe Storage, Handling, and Use of Commercial Explosives in Metal Mines, Nonmetallic Mines, and Quarries; Bureau of Mines Inf. Cir. 7380, 1946, pp. 16-18.

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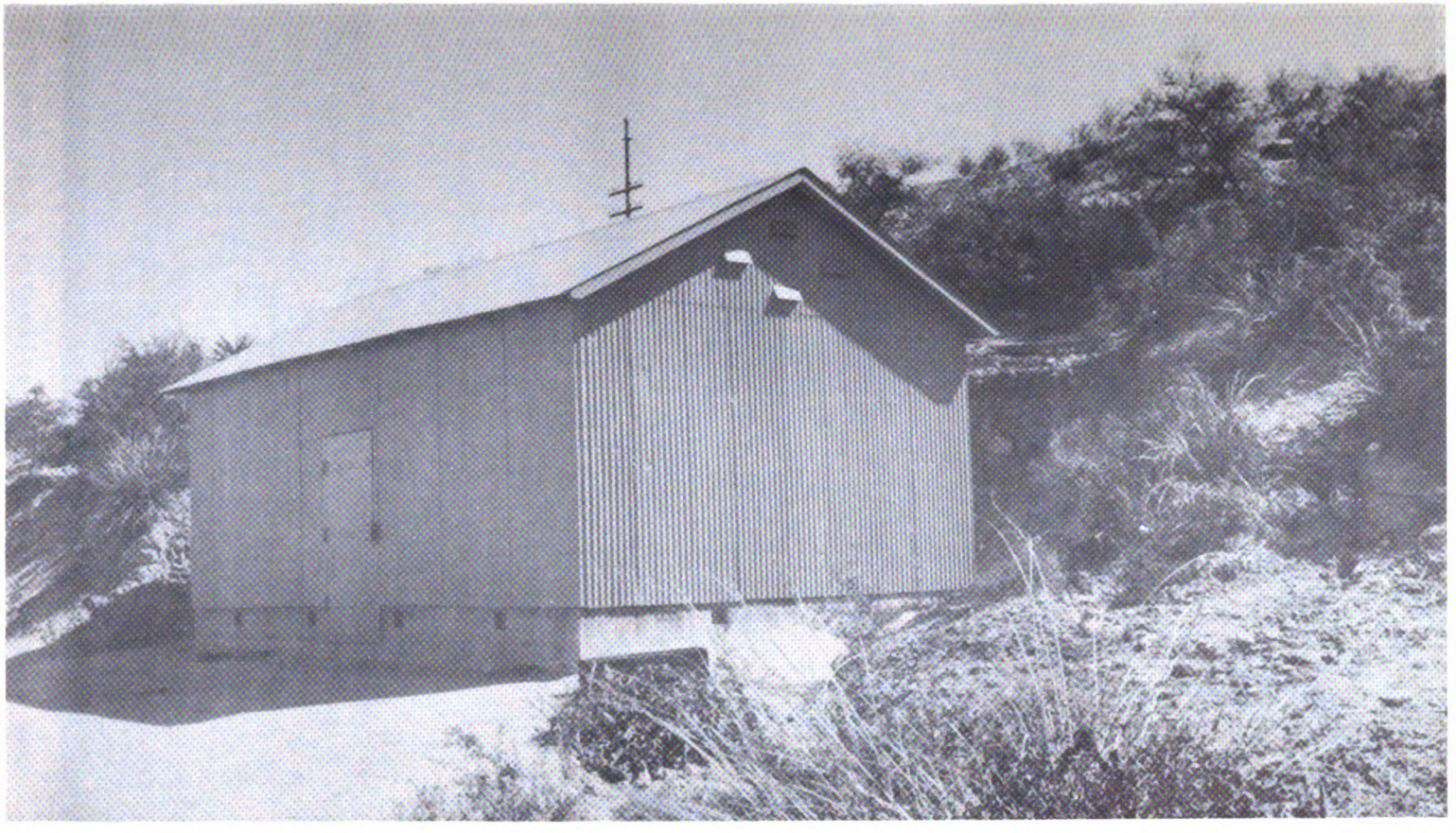

Figure 1. - Surface magazine.

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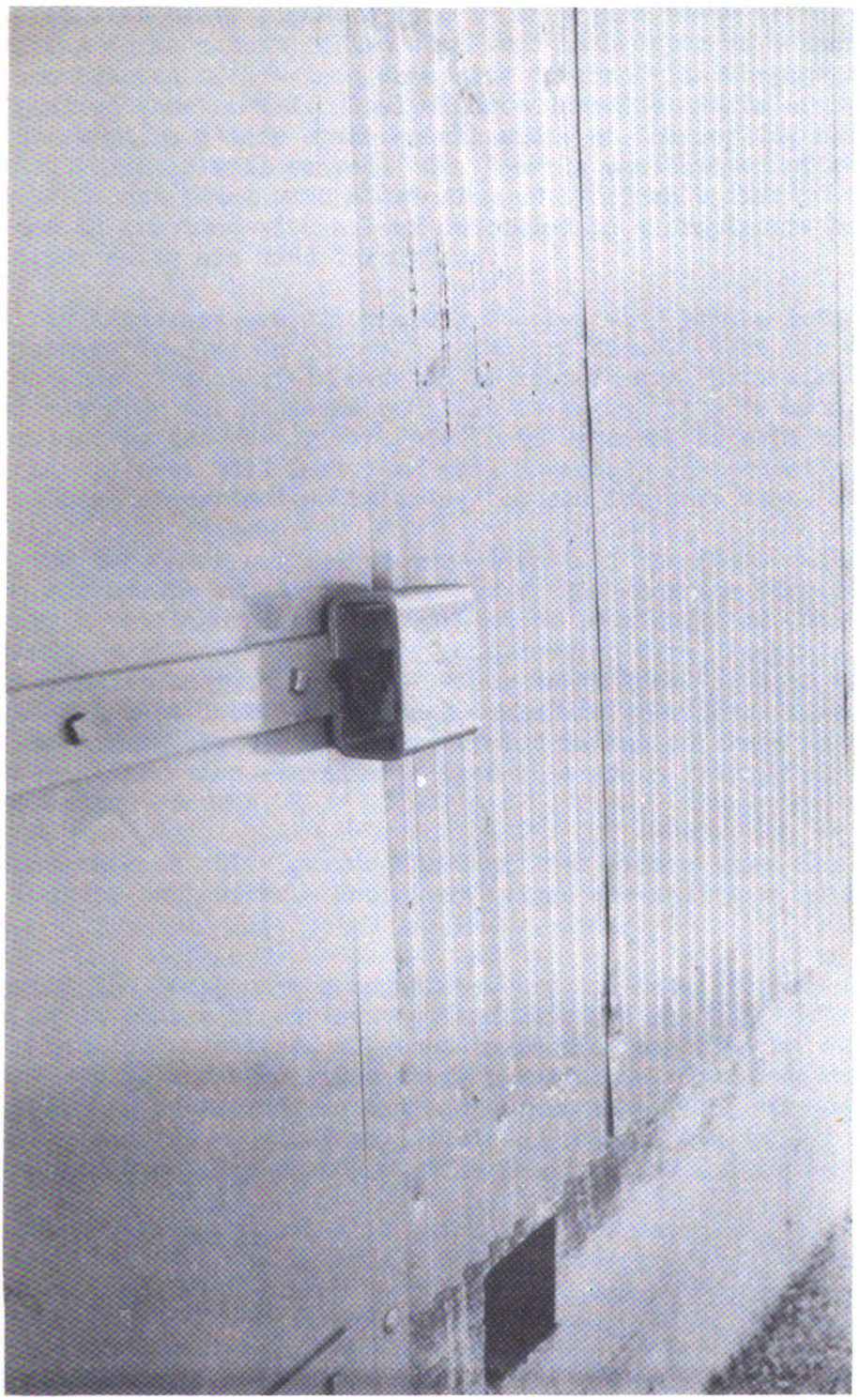

Figure 2. - Protective housing for magazine lock.

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and on the outside with 26-gage, corrugated, galvanized sheet metal. The floor is covered with heavy planks having 1- by 4-inch slats across the top. The ceiling forms a tray filled with sand to a depth of 4 inches. The roof is constructed of 3/4-inch sheathing covered with 26-gage corrugated, galvanized sheet metal. Twelve screened offset vents are around the base of the wall; a 2-inch space on all sides of the ceiling opens into the attic, which is well vented. The door is constructed of three layers of 1- by 8-inch plank with a covering of 3/8-inch boiler plate on the outside and is provided with a lock concealed in a protective housing (fig. 2). Copper nails are used throughout.

The two new magazines are alternately stocked with 30-ton lots of 1-1/8- by 8-inch explosives in 50-pound cardboard cases. When one magazine is emptied, another 30-ton lot is ordered to restock it. Explosives are taken exclusively from one magazine until it is empty, thus insuring that the oldest explosives are used first. As 15 to 25 cases of explosives are used daily, one shipment will last less than 3 months; consequently, there is little liklihood of explosives becoming too old for safe use.

Each of the two older surface storage magazines has adobe walls 2 feet thick on a concrete foundation, a floor of 2-inch plank with slats across the top, a ceiling tray filled with adobe to a depth of 10 inches, and a roof sheathed with 3/4-inch lumber and covered with 26-gage sheet metal. Doors consist of two layers of 1-inch board lined on both sides with 1/8-inch plate and kept locked. Screened vents are provided. Electric detonators (average of about 50,000) are stored in one of these magazines in wooden cases. The other magazine is used to store a maximum of 3,500 pounds of the shaped charges.

A watchman on each shift guards the magazines from a post overlooking the area. "Danger, Explosives - Keep Away" signs are posted at each magazine.

The keys to the locks on the magazine doors are kept by the warehouse foreman, who is in charge of explosives, and keys are given only to men authorized to handle explosives. Up-to-date records are kept of all supplies delivered to and taken from these magazines. The warehouse foreman accepts delivery of explosives and each month takes an inventory to verify his daily records. Rules for magazines, recommended by the Institute of Makers of Explosives, are posted at each magazine and are adhered to.

An auxiliary surface magazine is maintained for detonators in the mine yard. This magazine is a small frame building covered with corrugated metal sheathing, lined with lumber on the inside, and well vented. Approximately two cases each of nine different delay detonators are stored in this magazine. The wooden cases are opened with a brass hammer and chisel provided for that purpose, but the opened cases are not sent underground.

Underground Magazines

There are four main and two auxiliary underground magazines. Two main magazines, one for explosives and the other for detonators, are near the

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tool room on the 1,000 level; two are on the 900 level; and two auxiliary magazines are on the 975 level. Explosives and detonator storage magazines in each instance are over 50 feet apart. These magazines are lined with lumber, and their doors are kept locked. The magazines are kept clean, "no smoking" signs are posted within 50 feet of each, and fire-fighting equipment is near at hand. Compressed air is used continuously for ventilation. An electric light in each magazine is covered by Pyrex safety glass held in a heavy-duty socket and protected by a wire guard to prevent breakage. All wiring is in conduit.

The magazines on the 1,000 level supply explosives for the auxiliary magazines and the mine below the 900 level. The magazines on the 900 level serve that level and the mine above the 900 level. Approximately a 24 hours' supply is the maximum kept underground. Each of two main detonator magazines are stocked with a maximum of two boxes (50 detonators per box) of each delay or a maximum of 900 detonators.

Each tool-room attendant is responsible for the care of the magazines on his level. Blasting supplies are issued only on formal written order signed by the bosses, and no one other than the tool-room attendant is allowed in the magazines. When a magazine is unattended, the door must be locked. A daily record (appendix form 1) is kept by the tool-room attendant, containing data for each of the three shifts showing the blasting supplies on hand at the beginning and end of each shift, the supplies received, and those returned. This report is checked by the supply engineer against the written orders (appendix form 3) issued by the bosses.

Explosives are issued from the magazine only in sacks provided for that purpose, never loose or in the original cases. Detonators, blasting wire, or other materials are not placed in the bag with explosives. All empty explosive and detonator boxes are examined for "stray" pieces before being sent to the surface. Detonators, oils, or other combustibles are not permitted within 50 feet of an explosives magazine. A cartridge of explosive thought to be defective must be shown to the mine foreman, who gives orders regarding its disposal. The supply engineer disposes of old or defective explosives and detonators.

The auxiliary magazines are maintained because the hazard of carrying explosives and detonators along the haulage drift from the main magazines to the stopes would be greater than storing small quantities near the working area. These magazines are kept locked, and the bosses, in their respective jurisdictions, are responsible for them. Explosives and detonators are kept in separate magazines, which are adequate distances apart.

The underground magazines are not permanent installations and have been moved from time to time as mining progressed. The main magazines are so located that they are easily accessible but also at safe distances from the active workings.

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Replenishing Blasting Supplies

Explosives for the underground storage magazines are ordered daily in quantities based on data in the daily magazine reports. The supply engineer, who is responsible for blasting supplies delivered to the mine, fills out a requisition for explosives each day. The order is placed with the warehouse foreman by telephone, and the requisition sent by company mail is a check. Based on the telephone order, the warehouse foreman fills an order, which is given with the magazine key to the surface-magazine attendant. Esplosives are delivered to the mine-supply motorman before the lunch period at the surface landing of the supply shaft. The supply motorman signs for the explosives, and the order is approved in the mine office. The filled order, showing the explosives delivered, magazine number, and inventory taken at the surface magazine, is then returned to the warehouse foreman, who later attaches it to the requisition. Acceptance of the telephoned order instead of waiting for the written requisition permits daily deliveries of explosives based on the previous day's consumption. This permits the quantity of explosives in underground storage to be kept at a minimum consistent with production needs.

Detonators are ordered only as they are needed to replenish the supply in the surface auxiliary magazine. Each morning the supply motorman sends the required number of detonators to the underground magazines.

TRANSPORTATION

Explosives

The explosives for the mine are delivered in car-load lots at the railroad siding at Burch, Ariz., 6 miles away, where they are loaded into company trucks and transported to the surface magazines. The truck bodies are lined with lumber and are provided with explosive signs, tarpaulins, red flags, and chains to protect against static electricity. Trucks are not loaded above the sideboards, and all necessary safety precautions in the operation are observed.

A 1-1/2-ton utility truck delivers explosives from the surface magazines to the mine. The truck is provided with red flags, an explosive sign, and a chain to protect against static electricity. The floor of the body is lined with lumber when explosives are hauled. Each day, just before the lunch period, the explosives are transferred to a wooden mine car near No. 5 shaft. The maximum load of the mine car is 30 cases. After accepting delivery of explosives, the supply motorman is lowered on the cage to the 900 level, after which the explosives in the mine car are lowered without any person on the cage. The supply motorman then removes the explosives car from the cage, hauls it to the 900-level magazine with a storage-battery locomotive, and unloads the required amount. He then hauls the car to an elevator, lowers it to the 1,000 level, and delivers the explosives to the 1,000-level magazine. All of this work is completed before the end of the lunch period.

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Explosives in maximum loads of 50 pounds are carried in strong canvas bags from the underground magazines to the working places by the blaster. These bags are made especially for this purpose, colored red, and each is provided with a rope to close its opening and to hang it. The explosives must be kept in these bags after being removed from the magazines.

No scuffing, hurrying, or pushing is permitted when removing or returning explosives at the magazines; all explosives not used during a shift must be returned to the magazine at the end of the shift. When an ore or timber train is moving in a haulage drift, a man carrying explosives in the drift must retreat to a safe place until the train has passed. Smoking while handling or transporting explosives is strictly forbidden.

Detonators

Electric detonators in lots of 40 to 100 cases are delivered to the Miami railroad depot, from which they are hauled to the surface magazines in a truck equipped with a plank-covered bed, front and rear red flags, explosive sign on the rear, a chain to protect against static electricity, and tarpaulin. The same precautions are observed as in transportation of explosives.

A small truck, its floor covered with rubber belting and suitably marked, transports detonators from the main surface magazine to the auxiliary surface magazine.

Each morning, detonators in cardboard boxes (50 per box) are carried in red canvas bags to the underground magazines by the tool nippers. The nippers are lowered to the mine after the other shift men have descended. From the underground magazines, detonators are carried to the working places by the blasters or nippers in bags separate from the explosives. It is required that detonators be kept in their proper bags after removal from the magazines. The same precautions are observed in transporting and handling detonators as with explosives.

SUPERVISION AND USE OF EXPLOSIVES

The warehouse foreman is responsible for the receipt and storage of explosives on the surface and delivery to the mine. The supply engineer is responsible for the auxiliary detonator magazine on the surface, the transfer of explosives to the mine and underground magazine, and the storage of explosives underground.

The proper use of explosives is the responsibility of the shift foreman acting through the stope, development, and train-crew bosses. The following chart shows the line of authority in the use of explosives:

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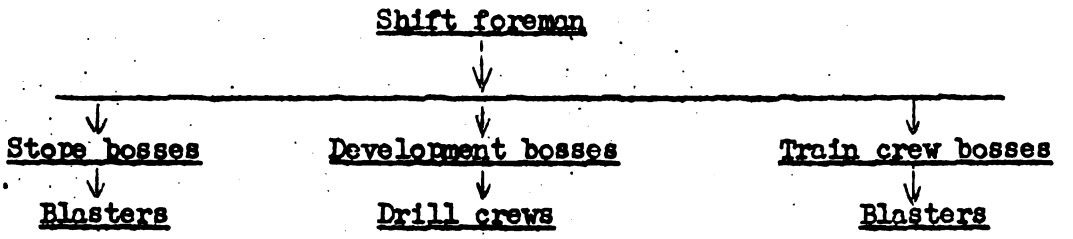

All blasting except transfer-raise blasting is done by the bosses, and explosives are issued at the underground magazines only on written orders signed by them.

In stope blasting, the shots are prepared and placed by the blasters. A blaster is qualified for his work by virtue of experience and other capabilities necessary to satisfy his boss. No employee is permitted to handle or use explosives without basic knowledge and proper instruction. In development blasting, the rounds are loaded by experienced miners. The blasters on the train crew also are qualified by experience to handle explosives.

Primary blasting in the mine is in development work of driving drifts and raises and in undercutting the blocks. Secondary blasting is done in the finger raises and transfer raises when the ore "hangs up."

ELECTRIC BLASTING

Electric blasting in the mine can be divided into three classifications, according to the source of current: (1) Most of the blasting is done from the main blasting switches by the bosses at lunch time and at the end of each shift. (2) Transfer-raise blasting on the haulage level is done as necessary by the train-crew bosses or blasters with permissible lamp batteries. (3) Transfer raises that are hung up, preventing the placement of an explosive charge from below, are blasted with a 10-cap capacity blasting machine from above by the stope boss when the raise cannot be freed with running water. Also, under circumstances such as when waiting until the regular blasting period would cause undue delay or danger as with misfires, where development is in an isolated part of the mine, or where blasting during the regular period would result in fumes passing where men congregate to eat lunch, blasting is done by the bosses with 50-cap blasting machines.

To check against overloading of explosives, each chute tapper is required to submit a "Chute Tapper Report" (appendix form 2), which shows the number of cartridges and detonators used for each finger raise. The chute blasters also submit a "Chute Blaster's Cap and Powder Report" (appendix form 4). These two reports are compared with the orders for explosives and detonators for consumption of blasting supplies. The stope engineers use the "Chute Tapper Reports" in preparing their monthly reports of each stope for the mine superintendent. This monthly report shows the explosives consumed, together with the tonnage produced and other pertinent information.

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If a round fails to fire, the electric circuit is examined, repaired as necessary, and the round is fired during the next regular blasting period.

After firing, rounds are inspected for misfires before other work is attempted. If the boss is not certain that all shots have exploded or whether the round has missed entirely, no one is permitted to enter the working place or places adjacent thereto until at least 5 minutes have elapsed and the blasting circuit leading into the place is broken, and precautions are taken to prevent accidental closure.

No attempt is made to extract explosives from a hole that has misfired, but in such instances a new primer is inserted above the missed charge, and no one is allowed to work in the place until after it is fired during the next regular blasting period. Miners are not allowed to deepen standing or abandoned blast holes that had been charged with explosives previously.

No rounds are connected with the firing line until a test has been made to determine that the blasting circuit is not "alive." No connections are made to the firing line until all men not actually engaged in connecting the charges have retreated to a safe place. Whenever possible, the last connection to the firing line is made under the supervision of the person in charge.

Blasting from Main Switches

Blasting Circuit

Both primary and secondary blasting is accomplished with power through main blasting switches of five blasting stations situated at the underground lunch rooms a safe distance (maximum of 2,000 feet) from active workings. The permanent blasting line is shown in the switch and wiring diagram (fig. 3).

The blasting switches are connected to the 275-volt, direct-current trolley line by two No. 4 wire conductors through a 100-ampere, 250- volt, 2-pole, type-A switch. The conductors are encased in rubber where they pass through moving ground and in lead where the ground is good.

Two special 60-ampere, 250-volt, 2-pole, type-A safety switches in parallel are installed at each blasting station. Each has been remodeled by including a spring to open the switch, thus giving positive release. A pilot light wired in parallel indicates when the switch is closed. The door and switch lever on each switch assembly are so interlocked that the switch cannot be closed when the door of the switch enclosure is open. The enclosing case of each blasting switch is frame-grounded, and the blasting circuit is protected with 60-ampere fuses at each main blasting switch.

A separate rubber-covered, type-S cable with two conductors extends from a blasting station to each stope or development heading served by that station. Each cable is connected to the switch by a patented plug. These plugs are "racked" below the switches and are labeled as shown in figure 4.

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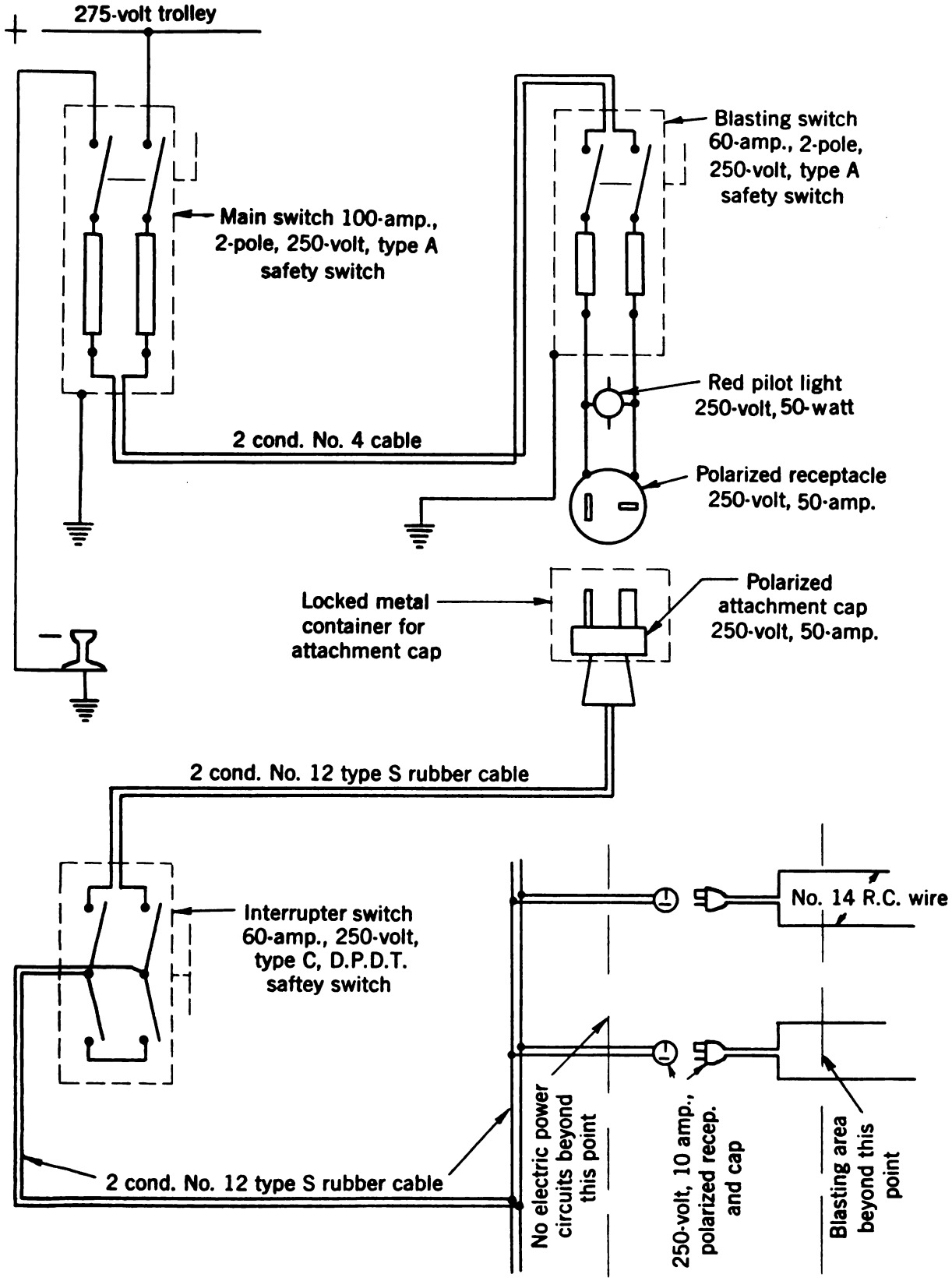
275-volt trolley
Main switch 100-amp., 2-pole, 250-volt, type A safety switch
Blasting switch 60-amp., 2-pole, 250-volt, type A safety switch
2 cond. No. 4 cable
Red pilot light 250-volt, 50-watt
Polarized receptacle 250-volt, 50-amp.
Locked metal container for attachment cap
Polarized attachment cap 250-volt, 50-amp.
2 cond. No. 12 type S rubber cable
Interrupter switch 60-amp., 250-volt, type C, D.P.D.T. saftey switch
No. 14 R.C. wire
2 cond. No. 12 type S rubber cable
No electric power circuits beyond this point
250-volt, 10 amp., polarized recep. and cap
Blasting area beyond this point

Figure 3. - Switch and wiring diagram showing permanent blasting circuit for stopes.

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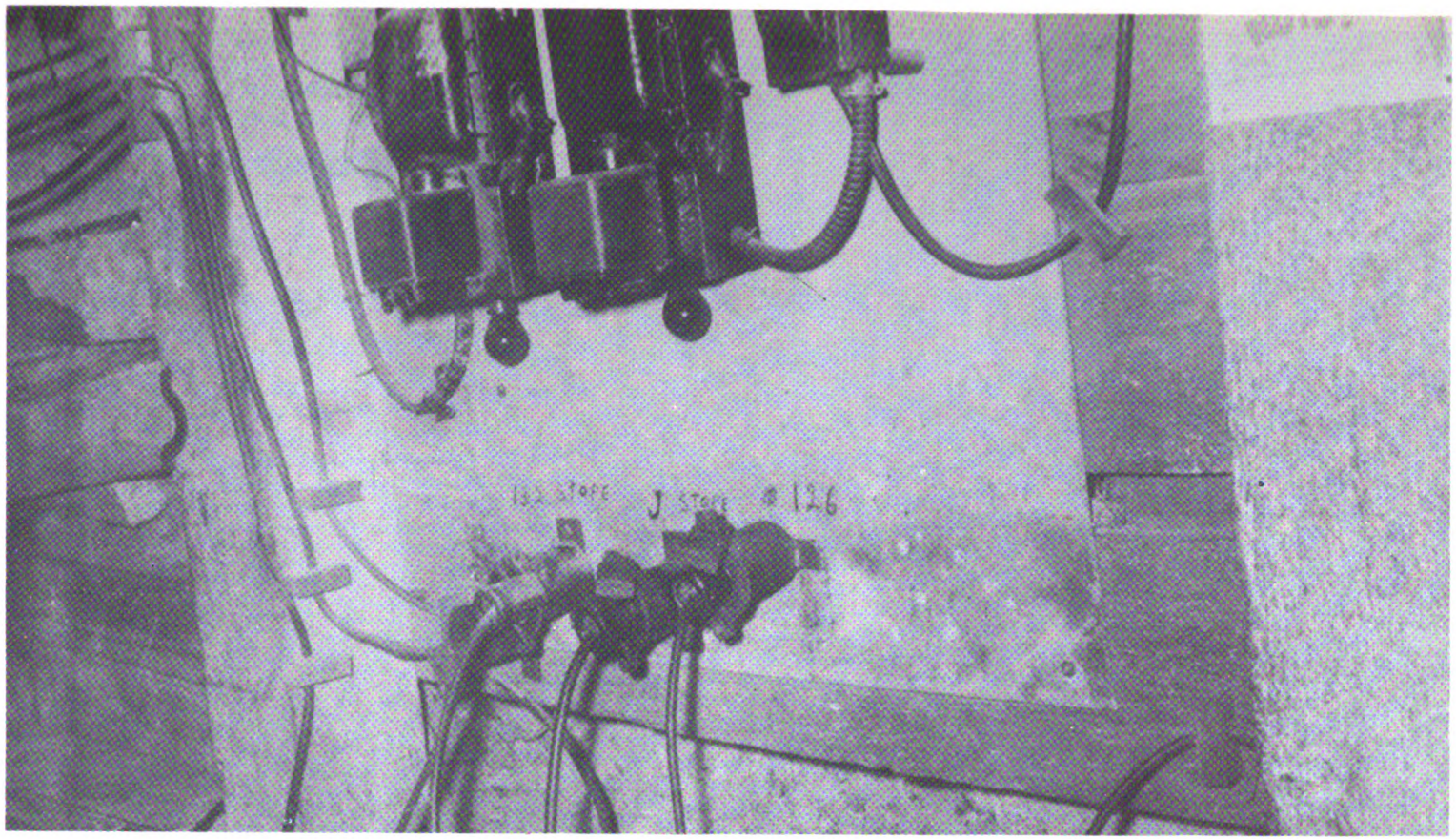

Figure 4. - Blasting station showing blasting switches and connection plugs.

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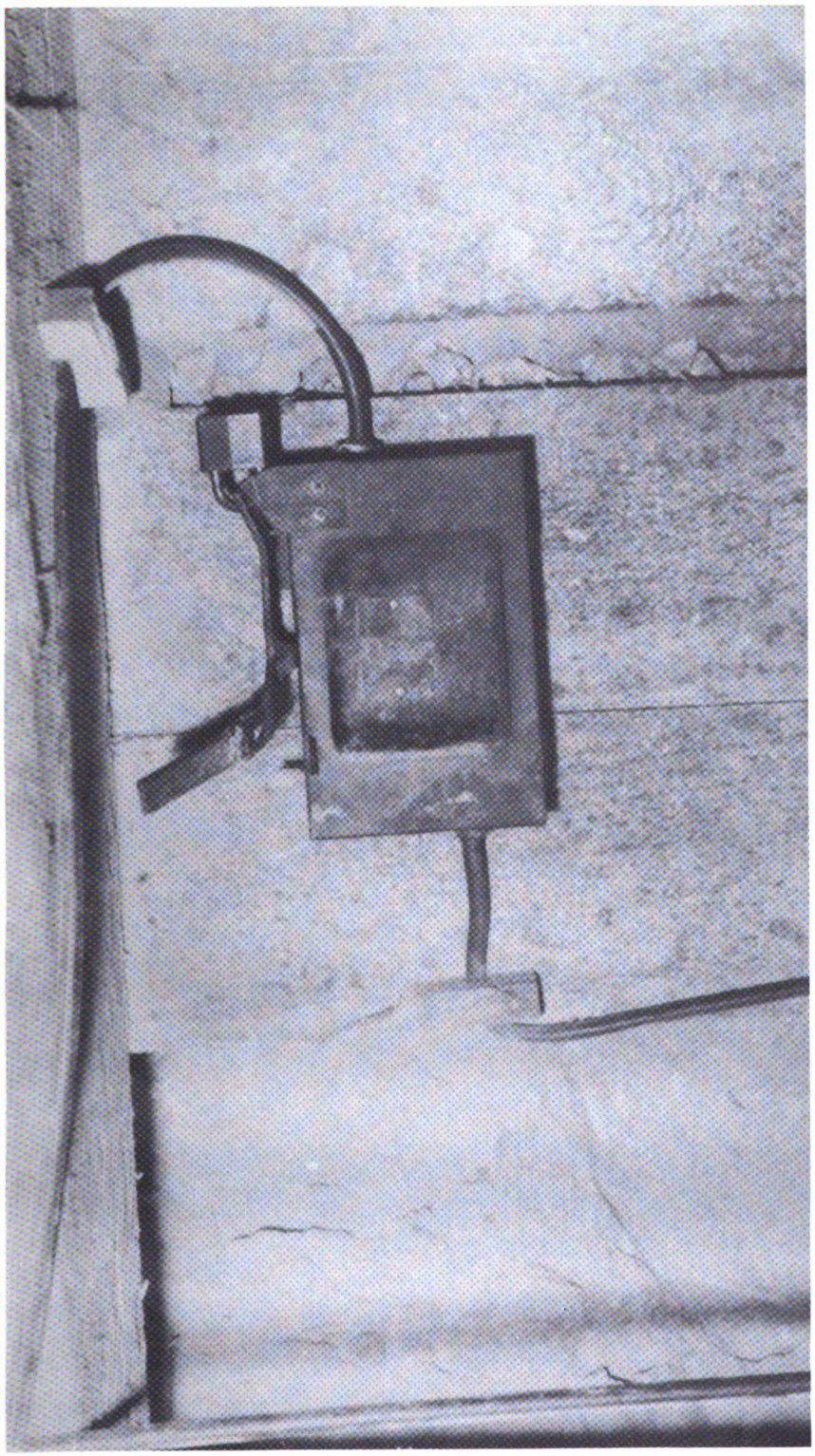

Figure 5. - Interrupter switch.

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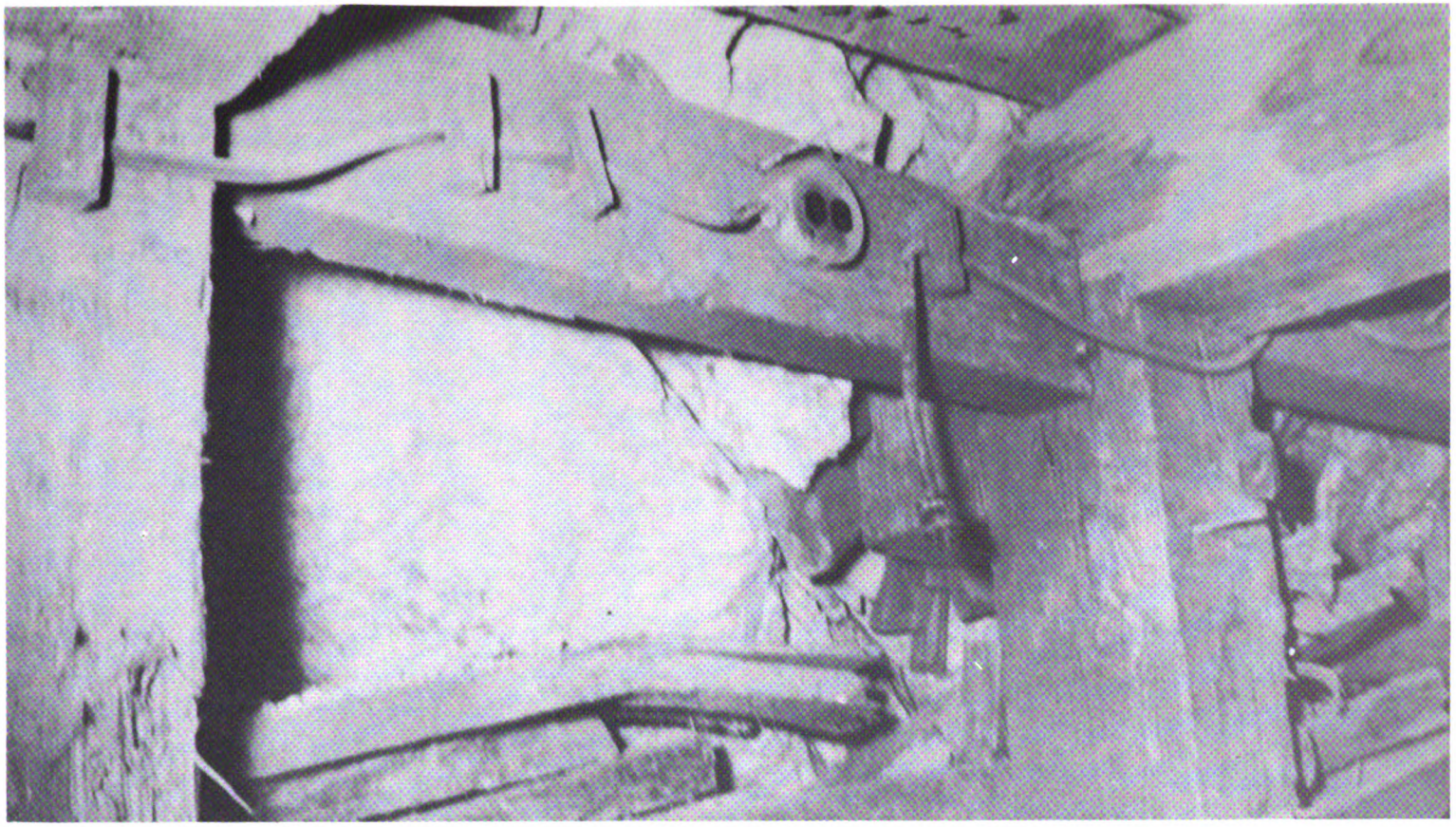

Figure 6. - Polarized receptacle and plug in grizzly drift blasting line.

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Each plug fits into a holder made of a 4-inch length of 3-inch pipe equipped with a device by which the plugs can be locked in place when disconnected from the blasting switches. To energize the blasting line to a stope, the lock on the plug holder on the blasting line from that stope must be unlocked, the plug must be inserted into a socket on a blasting switch, and the switch must be closed with the lever. Two contacts, therefore, must be made before a blasting line can be energized.

The conductors of the blasting circuit from the switches are of No. 12 wire if the line is less than 1,500 feet long and No. 10 wire if more than 1,500 feet long. Sometimes four No. 12 wires are used instead of two No. 10 wires.

An interrupter switch is inserted in each blasting line a safe distance from the stope or heading (fig. 5). The switch is so constructed that a lock holds the cover closed, and the lever in the "off" position. Two types of interrupter switches are used. One type is a nonfusible, shunt-type, 2-pole, type-C, double-throw, 60-ampere, 250-volt, safety switch that breaks the blasting circuit and "shorts" the blasting line to the stope when the lever is in the off position. This type is used in stopes in which there are electric-power lines. Whenever possible, the blasting circuit is carried on the side of a drift opposite other electric lines, but, if not, a minimum distance of 6 inches is maintained between blasting and other conductors. By short-circuiting the blasting circuit, the shunt-type interrupter provides protection in case ground-movement should result in moving the conductors closer together, tending to energize the blasting circuit. To insure against stray currents, the electrical equipment near a blasting circuit is well-maintained to prevent electrical leakage. Also, the interrupter switch is installed as near as possible to the stope (about 50 feet from the first grizzly drift). In the absence of electric-power lines, a standard 2-pole, type-D, 60-ampere, 250-volt, nonfused switch is used. The interrupter must be unlocked and closed before the blasting circuit beyond can be energized.

The blasting circuit in a stope is divided into parallel lines, one for each grizzly drift, each terminating in a 10-ampere polarized receptacle (fig. 6). Blasting-circuit conductors for development headings do not terminate at a receptacle, and the connection to them is made by splicing. Two conductors attached to a polarized plug are carried in each grizzly drift, with one No. 14 rubber-covered wire on each side of the drift. These lead wires are carried on special angle blocks spaced about 4 feet apart and attached to the posts and collar braces. Three turns of wire are taken around each block, leaving about 12 inches of extra wire between blocks to permit splicing of the lead wires in the event of a break. The leg wires of the electric detonators are spliced to the lead wires with connecting wires. Before the lead wire can be energized for blasting in a stope, the polarized plug must be inserted into the receptacle, or in development blasting the lead wires must be spliced to the end of the permanent blasting conductors. Thus, four connections must be made and two locks must be opened to complete the entire blasting circuit after the leg wires are spliced to the lead wires as follows: (1) The lead wires are connected to

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the permanent blasting circuit; (2) the interrupter switch is closed; (3) the plug is inserted into the blasting switch socket; and (4) the blasting switch is closed.

In development headings, the permanent blasting circuit is carried to within 100 feet of the face, and one twisted pair of No. 18 wire for each series group is used as lead wire. In blasting the undercut, the blasting circuit is extended to the top of the manway, and lead wires are extended therefrom to each series group. No. 18 wire is used to prevent occasional misfires that formerly occurred when No. 20 or 21 wire was used for long lead wires. Not more than 25 detonators are connected in series, and series groups are balanced electrically. Not more than 300 detonators are exploded at one time.

In stope blasting, the charges in four to eight grizzly drifts are blasted simultaneously with the blasting charges in each drift connected in parallel. The voltage with low line resistance is adequate for the maximum number of blasting charges normally required. Only detonators of the same manufacture are used.

Two blasting switches are used because, if a short-circuit occurs in one blasting circuit blowing the fuse in one switch, the remaining blasting circuits can be fired with the other switch (fig. 4). Another attempt then is made to fire the faulty circuit with the second switch, because it is possible for the short-circuit to burn itself out.

In case of misfires, or after unusual occurrence in blasting, such as the burning of a fuse, the underground electrical foreman is notified of the occurrence immediately. The trouble is cleared, and the round is fired during the next blasting period unless it is considered dangerous to delay firing until then.

Telephones are used extensively throughout the mine; one is provided at each blasting station. Condensers are not installed in the telephone lines in this mine.

Unauthorized persons are forbidden to touch electrical apparatus. If repairs or alterations are required on blasting circuits, blasting swtiches, or other electrical equipment, such work is done only by the mine electricians. One electrician patrols the mine on each operating shift to check the blasting circuits and make minor repairs, extensions, or adjustments. If major repairs are required, he notifies the electrical foreman, who assigns another man to do the work.

Under no circumstances are the main blasting circuits used for blasting except at the regular blasting periods. For any other blasting, a free and independent blasting line is used. The plugs at the blasting stations and the interrupter-switch enclosures are locked at all times when the switches are not being used for blasting.

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Preparation of Primary Blasting Rounds

Holes for blasting in drifts, raises, and in the undercut are drilled wet with jackhammers, stopers, and, to a less extent, with drifters. The ground is normally soft and easy to break. The drill rounds are not standardized, and the number of holes depends on the hardness of the ground and rests with the discretion of the bosses. The length of hole in the undercut ranges from a minimum of 3 feet to a maximum of 8 1/2 feet. After drilling is completed, all equipment is removed before blasting supplies are taken to the working face.

On order of the boss, the explosives are brought from the underground magazines by the "nipper" just before loading. Two men are at the face during charging of holes; primers are prepared at the face, the explosives are loaded direct from the sacks in which they are carried, and the charges are well tamped with a wooden tamping stick. A primer is prepared by punching a hole with a wooden skewer approximately in the center of the end of a cartridge and inserting a detonator so that it is entirely surrounded by explosive. The primer is placed near the bottom of a hole; one unprimed cartridge intervenes between it and the bottom; and the detonator points toward the bulk of the charge. The first and last cartridges are split. Stemming is not used, and the holes are loaded with approximately one cartridge per foot of hole. When the ground is unusually hard, which is seldom, all cartridges except the primer are split, thus loading the holes more densely. Where "up" holes are drilled, as in raises, all cartridges except the primer are split and tamped so that they will not fall out of the holes. Unused split cartridges often are returned to the underground magazines and can be utilized for secondary blasting. Cloth bags 5 by 9 inches are used for this purpose. Two split cartridges are placed in a bag, and the opening of the bag is closed and tied.

When loading in a heading that is within 40 feet of "holing through", operations are halted on the other side, and the men are ordered therefrom.

All loading and wiring of a large number of holes, as in mining level pillars and haulage drifts, must be done under the personal supervision of a boss, who sees that loading and wiring are done carefully. Each electric blasting circuit is tested with a galvanometer.

Preparation of Secondary Blasting Rounds

Explosives for blasting "hung" finger raises are obtained by the blasters at the underground magazines as they come on shift. The stope bosses give each blaster a written requisition before going underground, and each blaster is responsible for the explosives issued to him. He keeps the explosives and detonators in separate sacks and hangs each sack separately so as to prevent them from being struck by passing timber trucks or falling rocks. The blasters are instructed not to hang the sacks on or in contact with any pipe line, conduit, or electric cable. Explosives are not removed from a sack until immediately before preparing a charge.

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Boulders too large to pass the grizzly are broken with a hammer and feathering wedge. Blasting of boulders on the grizzlies is not permitted.

Pulling of muck in the grizzly drifts is stopped in time to permit loading before the lunch period or the end of the shift. A danger sign is posted at the entrance to the grizzly drift while the blaster is loading a round. For hung raises, a bomb if prepared by tying a 3-inch by 4 1/2-inch cartridge, or three or more 1-1/8- by 8-inch cartridges, to the end of a pole. The poles, ordinarily 1 inch x 1 inch x 9 feet, are spliced or cut to the required length to reach the muck in the hung raise. The bomb charge is primed by inserting an electric detonator in the end of a 1-1/8- by 8-inch cartridge or in the side of a 3-inch by 4 1/2-inch cartridge about 1 inch from the end opposite the cone-shaped depression. The detonator leg wires are kept shunted while preparing the bomb. The explosive charge then is tied securely to the end of the pole with heavy jute string. An extension of the desired length is made to the detonator leg wires with No. 20 or No. 21 connecting wire. The bomb is pushed up into the raise so that it rests against the muck and the pole is anchored in place by tying or wedging (fig. 7). The connecting wires are then tied to the lead wires in the grizzly drift, so that all bombs are wired in parallel.

When placing blasts in high chutes, a blaster must not stand on the bare grizzly rails but must use a lagging over the grizzly for safe footing. All bombs must be placed with blasting poles, and climbing under a hung raise to place a bomb by hand is prohibited.

When charging is completed, the blaster connects the lead lines to the blasting line by inserting the polarized plugs into their receptacles as he retreats. The stope boss investigates to be sure that all lead lines are plugged into the blasting line before closing the interrupter switch.

Blasting Procedure

After the rounds have been connected to the blasting line and the men have retreated from the area, each boss, who has a loaded round in his respective jurisdiction, unlocks the interrupter switch on his blasting circuit and then closes it. He then goes to the lunch room and checks in all his men as they arrive. After all bosses assigned to that station and having a round to blast have done likewise and have checked all their men, one boss, assigned to do so, phones the shift foreman, notifying him that all is clear and that he has a blast. If he does not have a round to blast, he nevertheless calls the shift foreman and notifies him that all is clear.

After all the bosses and supervisory force have called in and cleared themselves and their men, accounting for every man underground, including visitors, the shift foreman phones the bosses who have reported that they have a blast and notifies them that all is clear to blast. One boss at each blasting station then will insert the plug connection on the blasting line into one of the blasting switches and throw the blasting lever to close the switch. The red pilot light will indicate that the switch is closed.

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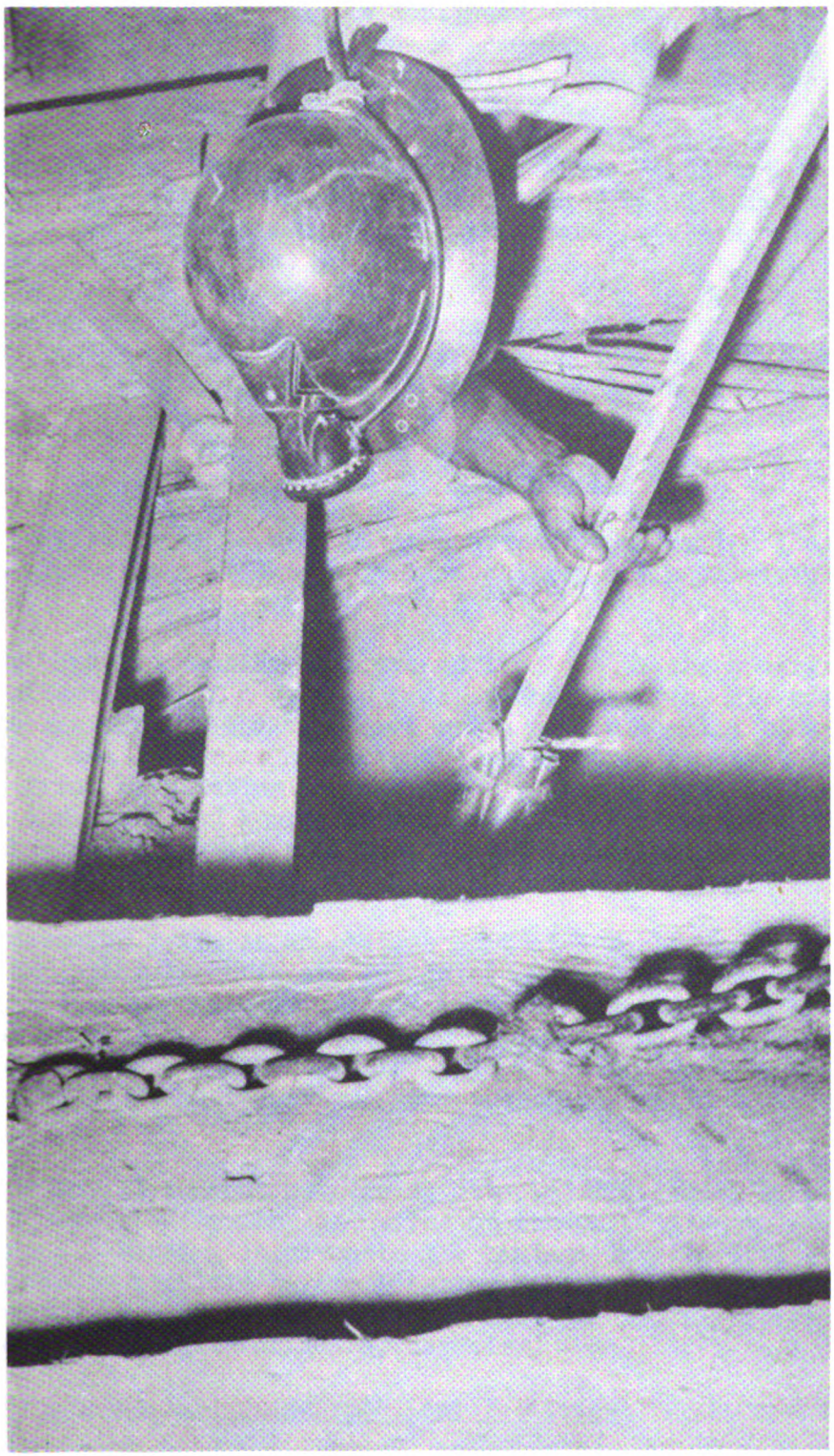

Figure 7. - Placing bomb in hung raise.

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After hearing the blast, he will open the switch and remove the plug from its receptacle. The process of inserting a plug, closing the switch, opening the switch, and removing the plug is continued until all blasts have been made. He then notifies the shift foreman accordingly. After all blasts have been reported, the shift foreman calls all blasting stations and lunch rooms and authorizes return to the working places.

Men leave their working places 10 minutes before the lunch period, and the blasting procedure is generally completed 5 to 10 minutes after the period; thus, 20 to 25 minutes elapse for the smoke to clear before the men return to their working places.

Each lock on the blasting circuit requires a different key. Duplicate keys are kept in the office, but each boss has underground the only keys that will unlock his circuit. After blasting, the locks are replaced on the blasting circuit.

Blasting with Blasting Machine

When a boss believes that conditions warrant a deviation from the normal blasting procedure, he must obtain permission from the shift foreman to do so.

A 50-cap blasting machine is obtained from one of the underground tool rooms along with a reel of a twisted pair of No. 18 wires. To prevent accidental hookup between the regular blasting circuit and a blasting machine, use of the latter is not permitted without independent lead wires. Rounds to be fired by blasting machine are wired in series. All men are ordered from the area, and guards are posted at all entrances thereto before blasting. The lead wires are connected last, and the actual blasting is done by the boss.

When a transfer raise is so obstructed that a bomb cannot be placed from below, the other branches are pulled clean, and a blaster, using a rope ladder, descends to the intersection of the branch and main transfer raise from which he places the bomb. The explosive, usually a shaped charge, is tied to the end of a pole and pushed into place. As many 9-foot poles are spliced together as is necessary to place the charge against the rock that is hung up.

No. 20 or No. 21 connecting wire is attached to the leg wires of the detonator and connected to the lead wires at the point from which the charge is placed. Warning is given to the haulage-level crews, and permission to blast is received before blasting in transfer raises. After guards are posted, the boss fires the bomb from the grizzly level, using a small hand-blasting machine of 10-cap capacity.

Blasting with Lamp Batteries

Blasting in a transfer raise from the haulage level is done when needed by placing a shaped charge in position, the same as in finger-raise blasting.

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Only the train-crew bosses and blasters are permitted to blast on the haulage level. These men are issued miner's lamps, each having a shot-firing attachment and distinctive marking to identify it as a blasting lamp. These lamp batteries furnish enough current to explode one electric detonator.

To prevent any possible error in blasting hung raises, the following precautions are observed:

1. The responsibility for obtaining clearance before blasting rests solely with the blaster, and he must obtain it directly from the boss on the grizzly level or from his own train boss. Other persons should not be involved in requesting or obtaining clearance.

2. In requesting clearance, the blaster or train boss must give his name and identify the raise to be blasted completely by giving the stope number, haulage line, and raise coordinates and inclination.

3. In giving clearance, the boss on the grizzly level must be sure that he is speaking with the one who requested it, give his name, and fully identify the rise to be blasted in the same manner as specified in the preceding paragraph.

Because all of the above must be consummated by telephone, it is imperative that both parties requesting and giving clearance be certain that the raise is identified beyond question of doubt. The haulage level also is guarded properly before blasting.

A 10-cap blasting machine formerly was used to blast from the haulage level, but quite often it was misplaced and lost. Blasting with lamp batteries has been satisfactory.

Ordinarily, a chute is not blasted with more than two cartridges of explosive unless the foreman directs otherwise. The power is cut off the trolley under the raise before a bomb is taken into a pony set or placed in a raise. Explosives are not placed or stored within 5 feet of live electric conductors.

SAFETY ORGANIZATION

Th company, fully cognizant of its responsibility for safety of its employees, endeavors to provide safe working conditions for all.

Each underground employee is given a book of instructions and rules, which set forth the precautions that must be taken by the men to protect themselves against the inherent and recurrent hazards of their employment. It is the special duty of foreman and heads of departments to see that the rules are observed, and any violations receive prompt attention. Failure to observe the rules is a valid cause for disciplinary action, including discharge for flagrant violations.

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Employees are solicited to offer safety suggestions, which are given prompt consideration.

First-aid supplies are provided at all underground supply rooms. All foreman, bosses, and tool nippers are required to take first-aid training provided by the company, and all employees are encouraged to attend these classes of instruction. An extensive first-aid instruction program was conducted recently, and during the first 6 months of 1949 748 of a total of 1,195 men employed at the mine and mill were awarded Bureau of Mines' first-aid certificates.

Upon entering his working place, each miner is expected to examine it, and if it is not safe he must make it so before beginning other work. This is particularly necessary with respect to loose or scaling ground, missed or cut-off holes, explosives or detonators in the muck pile, and damaged staging, timbers, and ladders or lack thereof. If the place cannot be made safe, a workman should vacate it immediately and report the condition to the foreman or boss.

A safety engineer is employed by the company for the mine and mill, but most of his time is devoted to the underground workings. He investigates all lost-time accidents at the scenes thereof as soon as possible and obtains accident information from witnesses, the boss of the section, and the mine foreman.

The company has recently received a "Certificate of Honor" award from the Joseph A. Holmes Safety Association for operating without a fatality from February 11, 1946, to March 1, 1949, during which time 13,145,672 tons of ore was mined with 4,386,236 man-hours of exposure. The no-fatality record has continued to the time of preparation of this circular.

CONCLUSION

The excellent accident record with the use of explosives at the Miami Copper Co. mine has been achieved by adhering to the following basic principles of safe blasting practice: (1) Accident risks are reduced by having as few men as possible handle explosives; (2) only careful men who have the necessary training and experience should be employed in blasting operations; and (3) regulations for blasting must be observed strictly.

Electric blasting is used exclusively at this mine; its safe use is due primarily to the following factors:

1. Over 95 percent of the blasting is done with the permanent electric blasting circuits, and the procedure affords protection to the men through use of the check-out system.

2. The permanent blasting circuit is never used for emergency or "on-shift" blasting. Emergency blasting is done with a blasting machine or lamp battery with separate lead wires, a foreman's permission must be obtained to do it, and the blast must be set off by a supervisor.

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3. All underground electric wiring and equipment are installed and maintained by the electrical department exclusively. Such installations are made as nearly perfect as possible, and a rigid daily maintenance patrol insures prevention of electrical leaks and faults.

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APPENDIX

Form 1

DAILY POWDER RECORD

	"A" SHIFT		"B" SHIFT		"C" SHIFT			
	FULL BOXES	EXTRA STICKS	FULL BOXES	EXTRA STICKS	FULL BOXES	EXTRA STICKS	LEVEL	DATE
On hand at start of shift								
Received during shift								
On hand at end of shift								
Returned at end of shift								

DAILY CAP RECORD

	"A" SHIFT		"B" SHIFT		"C" SHIFT			
	FULL BOXES	EXTRA CAPS	FULL BOXES	EXTRA CAPS	FULL BOXES	EXTRA CAPS	LEVEL	DATE
On hand at start of shift								
Received during shift								
On hand at end of shift								
Returned at end of shift								

Signed: "A" Shift Toolroom Attendant _____

"B" Shift Toolroom Attendant _____

"C" Shift Toolroom Attendant _____

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Form 2

CHUTE TAPPER REPORTS

_____ Stope _____ Shift _____ 194____

Chute	Tons		Time		Condition of Chute						Cone bombs
	Max	Drawn	From	To	Times blasted	Boulders	Packed	Sticks of powder	Caps		

Blaster No. _____

Tapper No. _____

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Form 3

BLASTING AND POWDER ORDER

Delay Caps Needed

_____ 0-3 Ft
_____ 0-8 Ft
_____ 1
_____ 2
_____ 3
_____ 4
_____ 5
_____ 6
_____ 7

WARNING - Do not fire your blast under any condition unless I tell you to.
ADVERTENCIA - No prenda fuego a su barreno bajo ninguna circunstancia sino hasta que yo se lo indigue.

PLACE	KIND OF WORK	STICKS OF POWDER	TOTAL CAPS

Level _____ Date _____

Shift _____ Payroll No. _____ Boss _____

Form 4

CHUTE BLASTER'S CAP AND POWDER REPORT

Cone Powder

Issued _____

Returned _____

Used _____

Stick Powder

Issued _____

Returned _____

Used _____

Blasting Caps

Issued _____

Returned _____

Used _____

Date _____ Level _____ Shift _____

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